6. Small Air Cleaning Units

6.1 INTRODUCTION

This chapter discusses the installation of internal components, primarily HEPA filters, in systems that require only a single filter per stage of each air cleaning unit (Sect. 2.4.9). Although installation requirements are generally the same as those for multifilter housings (Chap. 4), the use of questionable practices in some older systems and the proliferation of commercially built off-the-shelf housings (caissons) make a separate discussion of this subject desirable. Single-filter (i.e., nonparallel) installations are employed in the supply, exhaust, and recirculating air cleanup systems of rooms, glove boxes, hot cells, chemical fume hoods, and other contained spaces; in the off-gas lines of process vessels and radiochemical operations; and in other applications in which the airflow is 1500 cfm or less. Single-filter installation for glove boxes is a separate topic and is covered in Chap. 7. Although the discussion in this chapter centers about the installation of HEPA filters, it also applies to adsorber cells and other components for which a better than average installation is necessary.

The design of the filter (adsorber) installation is a function of the configuration of the filters (adsorbers) used. Section 3.2 describes three general HEPA filter configurations: open-face rectangular (with wood case or with steel case having double-turned flanges on each face, as shown in Fig. 3.2), open-face cylindrical (with molded-phenolic or metal case, with or without flanges on one or both faces), and enclosed (Fig. 3.3). The enclosed configuration may be either rectangular or cylindrical; it consists of a core, identical to that of the equivalent open-face filter, which is sealed into an elongated case with a closed end and nipple on one or, more often, both ends. The nipples of the enclosed filter may be plain, as shown in Fig. 3.3, or flanged. The rectangular open-face filter is most commonly used in both large-volume (multifilter) and low-volume (single-filter) applications, and this chapter deals mostly with this type of filter. The installation of cylindrical open-face filters and enclosed filters is discussed in Sects. 6.4 and 6.3 respectively. Any HEPA filter size other than those listed in Table 3.1 should be considered as a "special" with respect to procurement.

Single-filter installations can be grouped into three broad categories: in-wall (filter mounted in or to a wall penetration of a room, glove box, hot cell, or other contained space); in-duct (filter installed "in the line" between two sections of duct, with or without transitions); and duct-entrance (filter installed at opening of duct leading from a room, glove box, hot cell, or other contained space). In-wall installations are generally employed to clean the air entering a contained space, to prevent the backflow of contamination in the event the contained space becomes pressurized, or both. The filter may be installed bare (sides of case exposed) or in a partial enclosure. As in other installations, a prefilter is recommended upstream of the HEPA filter. Duct-entrance filters are strongly recommended to maintain the cleanliness of contaminated exhaust and air cleanup ducts. They should be mounted in or close to the entrance of the duct and, like the in-wall type installation, may be installed either bare, as Fig. 6.1 shows, or in a partial enclosure.

In-duct open-face filters should be installed in totally enclosing housings or caissons as shown in Fig. 6.2. Common practice in the past, however, has been merely to tape or clamp the filter between two sections of duct or a pair of duct transitions, with the case exposed, as shown in Fig. 6.3. Such installations provide no secondary containment in the event of a breach of the filter case or gaskets, or the tape seals, and, particularly for wood-cased filters, these installations fail to meet the requirements of UL-181 and NFPA 90A.[1,2]

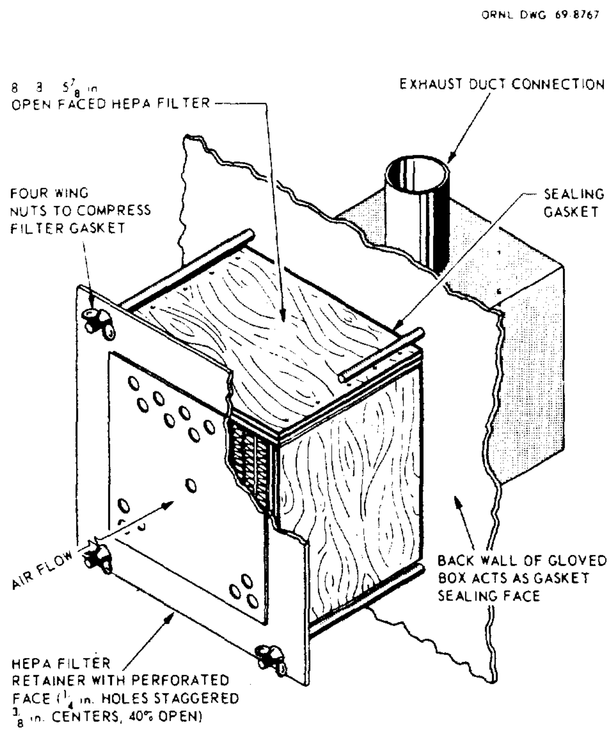

Fig. 6.1. **Duct-entrance or in-wall HEPA filter installation without enclosure.** Note protective perforated plate on exposed face to prevent physical damage to fragile core of filter.

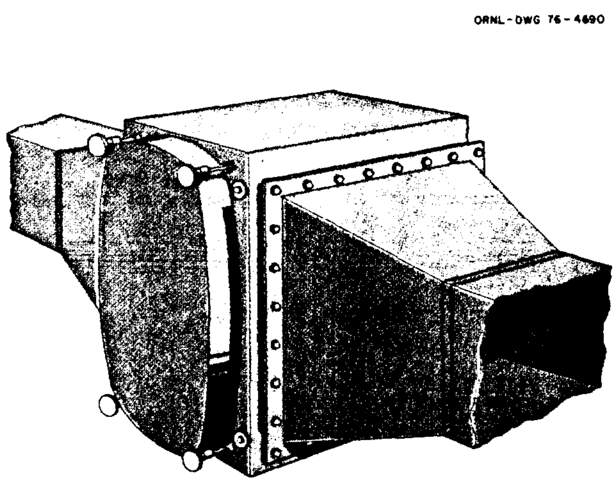

Fig. 6.2. **In-duct HEPA filter installation.** Filter installed in total enclosure or caisson.

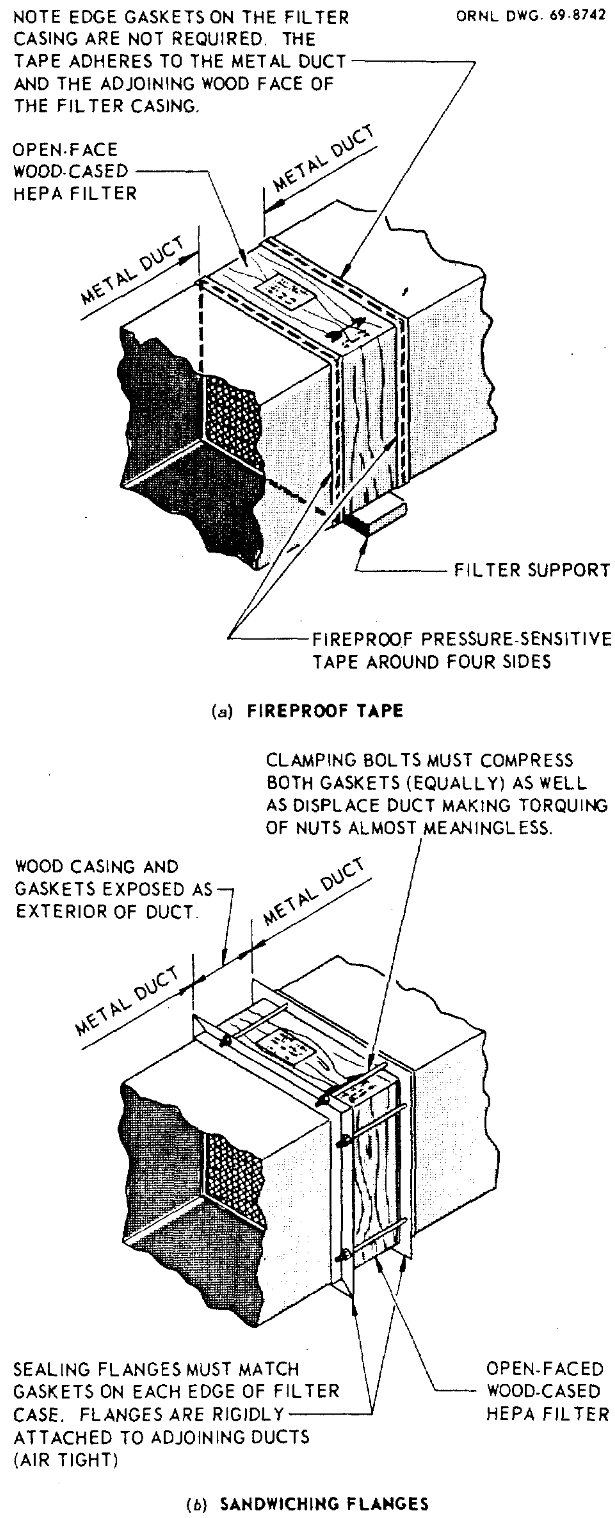

Fig. 6.3. *Common in-duct filter installation methods.* These are not recommemded for contaminated exhaust or recirculating air cleanup applications where high integrity is required.

6.2 HOUSINGS

Housings for in-duct installations may be as small as the mini-caisson for a 25-cfm HEPA filter or as large as the complete multistage air cleaning unit, containing demister, prefilter, two stages of HEPA filters, and adsorber, shown in Fig. 6.4. Figure 2.13 shows a concrete-enclosed single-component air cleaning unit. Probably the most common single-component housing today is the bag in, bag out caisson which is commercially manufactured by a number of companies to a more or less standard configuration. Figure 6.5 shows several commercial single-filter housings.

Commercially made caissons, like other air cleaning system components, are not items to be selected "on faith." Designers have been prone to look upon these as "black boxes," believing that, because they are off-the-shelf items, they can be assumed to be of adequate design and to be suitable for any nuclear application. Such is not the case, and some users have been faced with replacing or upgrading many such commercial enclosures over the past several years. Features that must be checked carefully when purchasing standard commercial housings include the filter (component) mounting frame and clamping device, the rigidity of the box and its cover, the method of cover sealing and clamping, access to the installed component, the rigidity and construction of duct connections, and the materials of construction of all parts, including the component clamping mechanism. These same features are of importance in the design of one-of-a-kind shop-built housings.

6.2.1 Component Installation

Requirements for installation of components are basically the same as those for bank installations (Sect. 4.2) and include structural rigidity, flatness, and accuracy of construction of the mounting frame; positive and reliable seal of the component to the frame; specification of and strict adherence to close tolerances in fabrication; and leaktight welded construction. A minimum sheet-metal thickness of 0.078 in. (No. 14 U.S. gage) and preferably 0.125 in. (No. 11 U.S. gage) is recommended for mounting frames of commercially made and shop-fabricated housings. The mounting frame must be seal-welded into the housing in such a manner that no warping of the filter (component) seating surface will result. There should be a right-angle bend all around the seating surface to provide reinforcement and to ensure flatness. Figure 6.6 shows a portion of the turned-angle filter seating surface of a commercial housing and the four-bar-

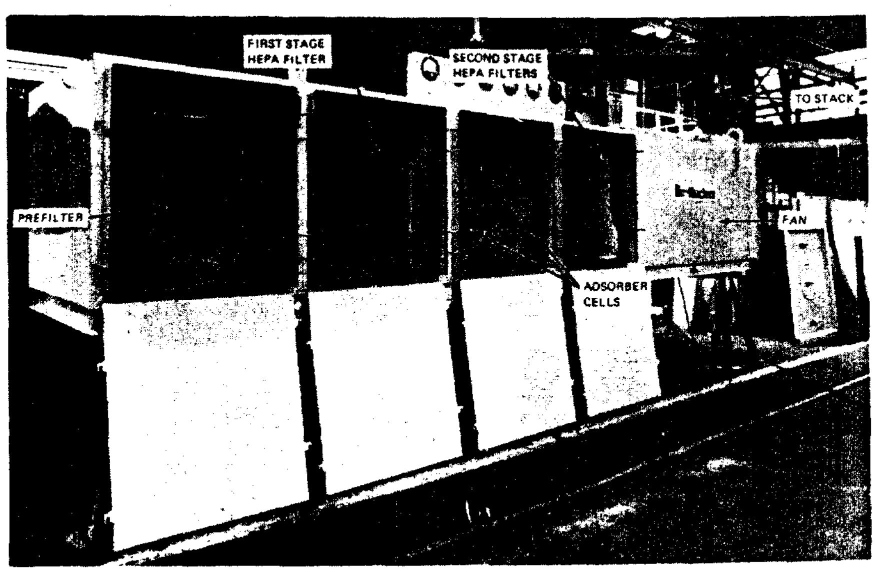

Fig. 6.4. Self-contained, unitized air cleaning unit with prefilter, HEPA filter, two type II adsorber cells, and second HEPA filter. Fan located within housing at right, connections to inlet and stack flanges on top of unit. As shown, unit is designed for airflow of 333 cfm with adsorbers arranged in series. With a single stage of adsorption, unit could be rearranged for 1000-cfm airflow by removing the baffle between the adsorber cells. Courtesy U.S. Army, Aberdeen Proving Ground-EA.

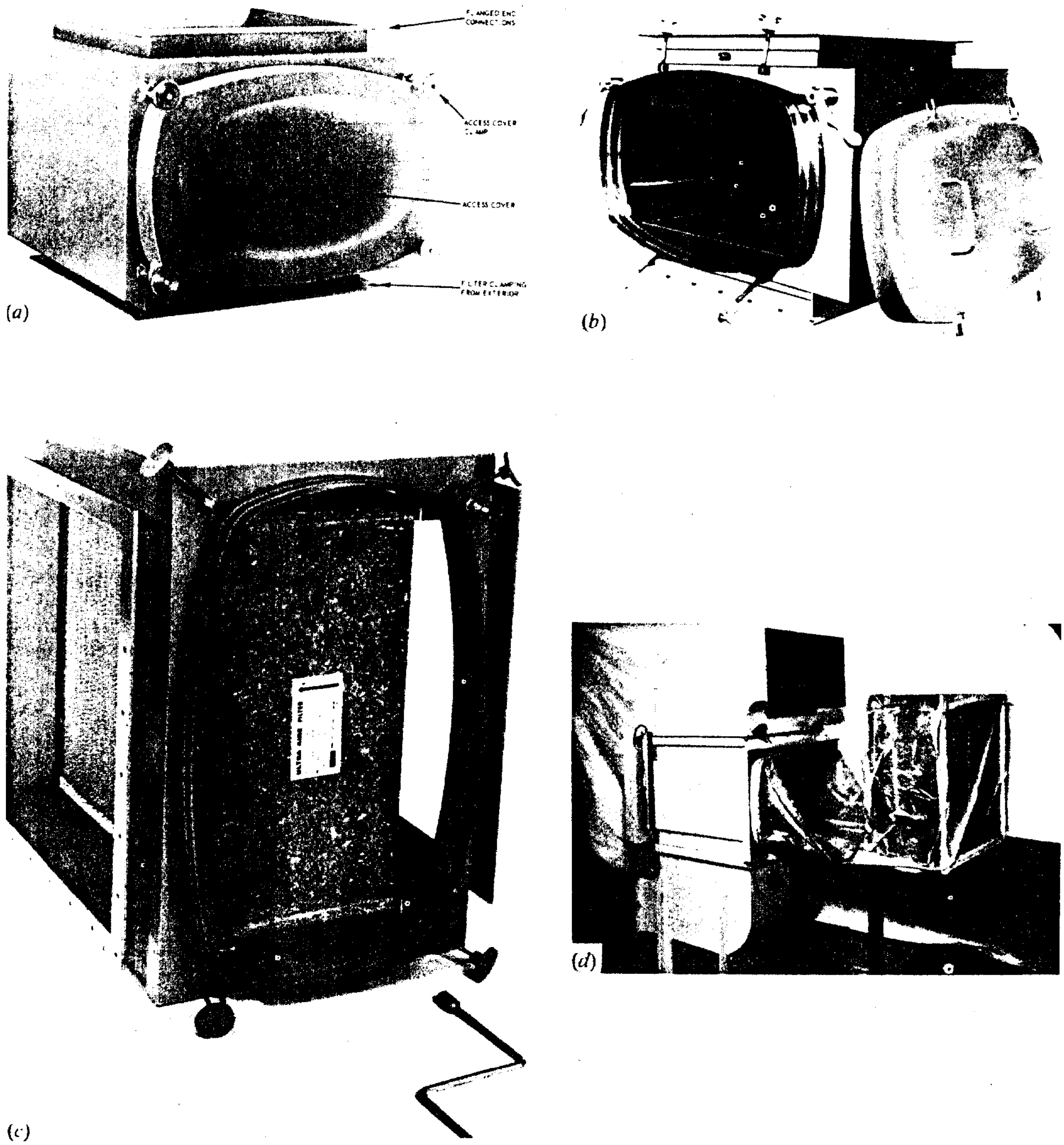

Fig. 6.5. Commercially manufactured single-filter housings. (*a*) SGN *Caisson*, made by Barnebey-Cheney, Columbus, Ohio. (*b*) NCI modular filter enclosure, made by Nuclear Containers, Inc., Elizabethton, Tennessee. (*c*) MSA *Ultra-lok*, made by MSA Co. Note design to accommodate filter in either vertical (preferred) or horizontal orientation. Note crank for operating four-bar-linkage clamping mechanism from outside of the housing. (*d*) Vokes UNIPAK, made by Vokes, Ltd., England. Courtesy United Kingdom Atomic Energy Authority.

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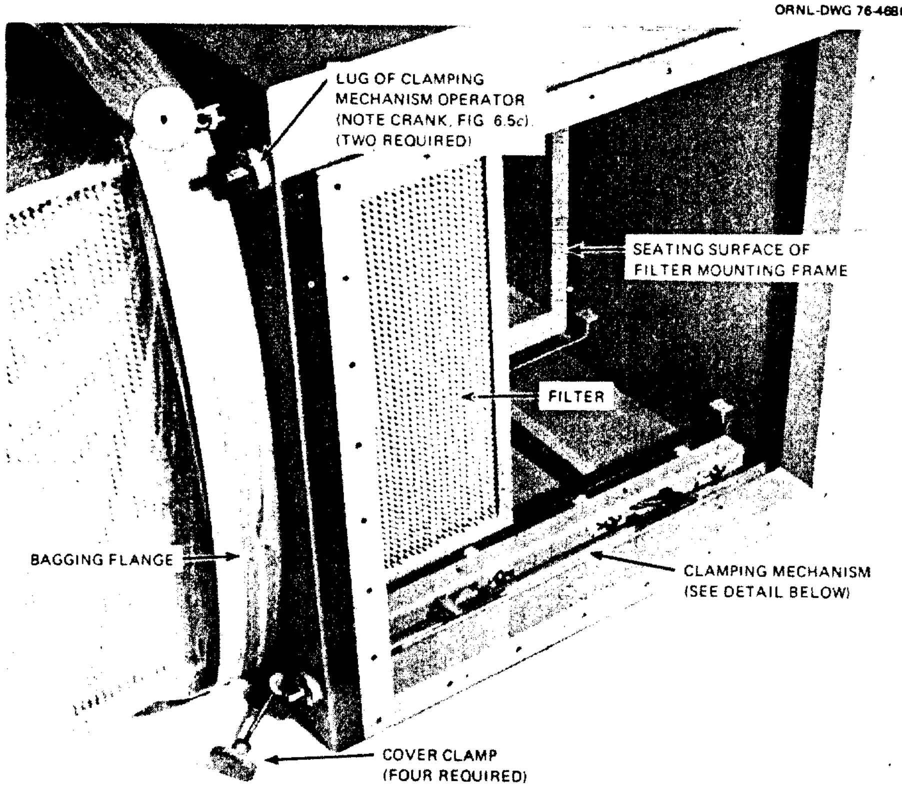


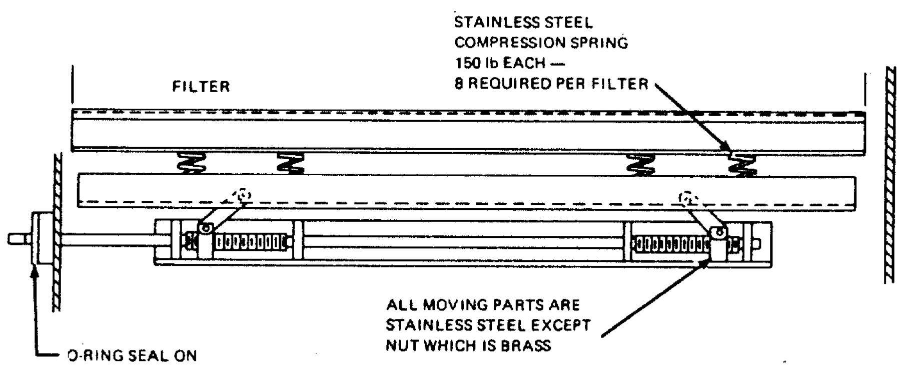


Fig. 6.6. Typical commercial single-filter housing showing important features and details of a typical clamping device. Courtesy MSA Research Corp.

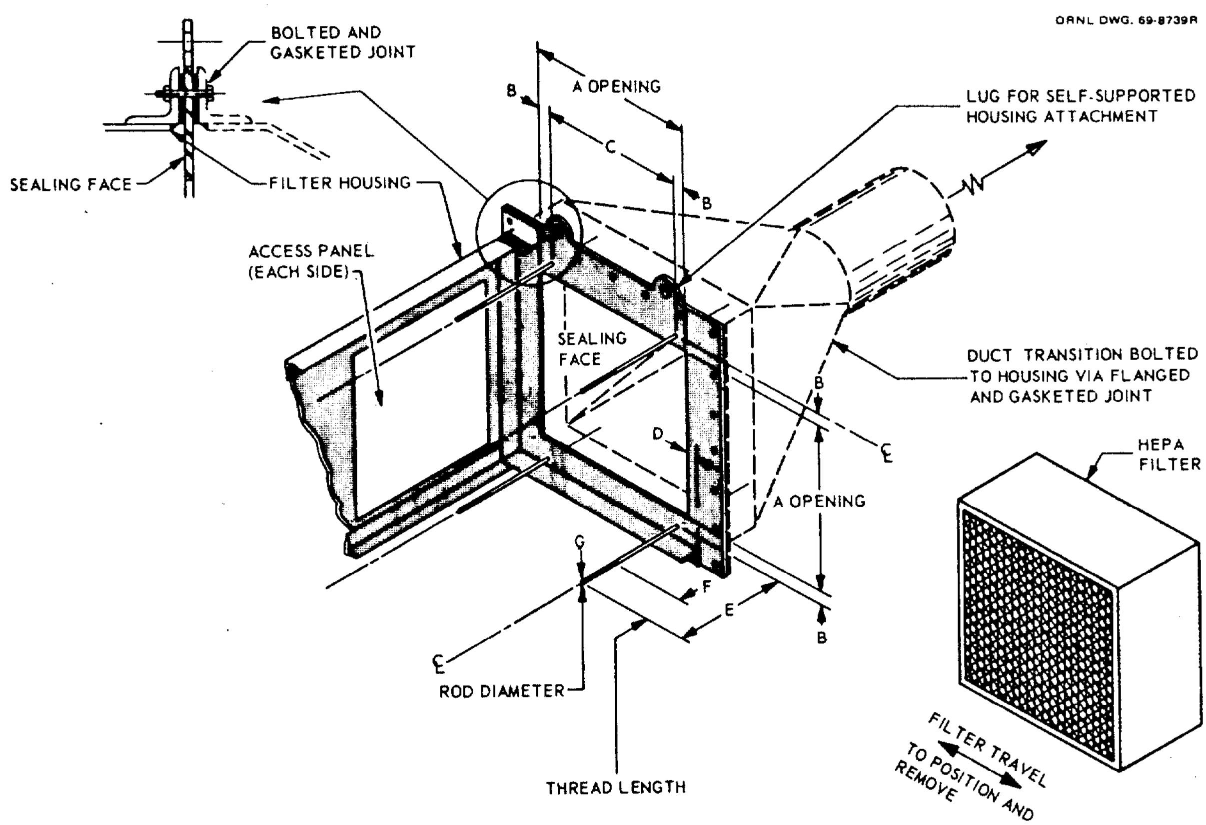
linkage clamping mechanism that is operated by means of a wrench (Fig. 6.5*c*) from outside the cabinet. Structural requirements of the mounting frame will be met if the 14-gage or 11-gage steel is used, particularly if the stiffening flange (right-angle bend) is used. Face mounting of the filter to the mounting frame is recommended, with a "finger space" of at least 2 in. on two sides, as shown in Fig. 6.5*c*, for ease of access and filter replacement. Access space within the housing is particularly important in bag in, bag out housings. The frame fabrication and tolerance recommendations of Sect. 4.3.3 are applicable to both commercial and shop-built mounting frames. Either the flat-gasket-to-flat-flange or the fluid seal described in Sect. 4.3.4 is recommended. Flat-gasket-to-knife-edge seals tend to leak excessively if the knife edge is nicked, or if there is any lack of parallelism between the knife edge and the filter face; the compression set produced by a knife edge in only a portion of the gasket also results in leakage if there is any degree of relaxation of the clamping device.

Figure 6.7 shows a nonwelded mounting frame consisting of a single ¼-in. plate that is sealed by gaskets between the flanges of the body and transition of a field-assembled housing. The filter is clamped by bolts and installed through a hatch in the side of the housing. As noted in Chap. 4, bolted clamping provides the maximum in reliability (provided the bolts are large enough) and ability to adjust to dimensional variations of the filters. As noted in Sect. 4.3.4, a gasket compression of at least 80% is needed to effect a reliable seal between a high-efficiency device such as a HEPA filter or radioiodine adsorption cell; this requires a gasket loading of something over 20 lb per square inch of gasket area, or a total loading of over 1400 lb for a 24- by 24-in. filter. Such loadings are easily accomplished with the bolted clamping method shown in Fig. 6.7. Most commercial single-filter housings, however, employ a four-bar linkage or cam arrangement, of which those noted in Figs. 6.5 and 6.6 are typical. Some are adjustable to accommodate dimensional variations that occur from one filter element to the next, and some are not adjustable. It is important for the designer to verify that the clamping mechanism of the commercial housing he is considering can develop the loading required and is adjustable. All parts of the mechanism should be stainless steel to prevent rusting and seizing under operational conditions. This includes springs, which tend to break when rusted. The only exception to this rule is that nuts, if used, should be brass, bronze, or other material that will not gall in contact with the stainless male-threaded part (Fig. 6.6). Suggested values for critical dimensions of the mounting frame are given in the table of Fig. 6.7. Clamping mechanisms should be on the clean side of the filter, and operator shafts, when required, must be sealed by O-rings, as Fig. 6.6 shows, or glands. A rest, guides, stops, or other means for aligning the filter prior to clamping should be provided within the housing.

The clamping pressure required to properly seal a gasket-sealed HEPA filter or adsorber cell must be both high and uniform, as noted in Sect. 4.3.4. However, this requirement is substantially relaxed when the fluid seal system[3] is used. As Fig. 4.18 shows, the filter element has a groove filled with a non-Newtonian (i.e., nonflowing) fluid. The filter is pushed against the knife edge flange of the mounting frame so that the fluid comes in contact with some fraction of an inch of the knife edge, thus forming an airtight seal. Clamping pressure need only be sufficient to prevent the filter from backing away from the knife edge (which would break the seal) under any foreseeable differential pressure across the filter under either normal operating or system upset conditions. The fluid, a silicone compound, has been tested and found to be capable of maintaining an adequate seal under the fire and hot air conditions of UL-586[4] and the radiation exposure requirement of MIL-F-51068-D.[5]

6.2.2 Housing Construction

The walls of the housing must be sufficiently strong to prevent "oil canning" and overstressing under an alternating positive and negative pressure equal to at least 1.5 times the maximum absolute gage pressure to which the housing will be subjected, under the most severe conditions for which it is intended (i.e., usually a DBA); a minimum design pressure of 10 in.wg is recommended. In general, the design and fabrication recommendations of Sect. 4.5.2, and the leaktightness recommendations of Sect. 4.5.8 are applicable to housings of these smaller dimensions. In purchasing commercial housings, the designer should check the details of construction to verify that the design proposed is, in fact, adequate for his application; that is, that the walls of the housing (or the cover) will not "oil can" and that stresses in the walls or clamping mechanism will not exceed a value of 0.7 times the yield strength of the material from



Filter Size (in.)	Frame Dimensions in Inches							
	A	B	C	D[a]	E	F	G[b]	H
8 × 8 × 3 1/16	6 1/4	1 1/4	3 3/4	1 1/8	5 1/4	1 1/2	3/8	1/2
8 × 8 × 5 7/8	6 1/4	1 1/4	3 3/4	1 1/8	8 1/4	1 1/2	3/8	1/2
12 × 12 × 5 7/8	10 1/4	1 1/4	7 3/4	1 1/8	8 1/4	1 1/2	3/8	1/2
24 × 24 × 5 7/8	22	1 1/2	19	1 1/4	8 1/4	2	1/2	3/4
24 × 24 × 11 1/2	22	1 1/2	19	1 1/4	13 3/4	2	1/2	3/4

[a]D = width of prepared sealing face around A by A opening.
[b]Shouldered nuts not shown but one is required for each bolt.

Fig. 6.7. Details of typical owner-designed single-filter housing showing important dimensions applicable to commercial and one-of-a-kind housings.

which they are made under a housing pressure of 1.5 times the design pressure.

Many failures of commercial housings can be traced to corrosion. The filter housing is a common point where corrodents tend to condense, collect, and concentrate. When the filter housing is to be installed in a line which may, under either normal or abnormal conditions, contain corrosive fumes or vapors, stainless steel construction should be employed. In any event, all parts of the clamping device (including springs, but not nuts) should be of stainless steel. The designer should determine what coating has to be used and establish, to his personal satisfaction, that it is adequate for his application (10 to 20 years service life is often considered normal for such housings; 40 years is a figure often expressed for nuclear power reactors). Results of chemical-resistance tests, as specified in ANSI N512,[6] should be reviewed in such evaluations.

The housing cover should be attached by hand nuts of the type shown in Figs. 6.5 and 6.6. Attachment of covers with machine bolts or nuts may be cheaper but will be a constant problem to the user. Nuts get lost and threaded bolts get damaged under service conditions; the result is often the inability to seal the housing properly, and the need to remove and replace a large number of nuts or bolts inhibits access and proper service. For hand-nut cover clamping, the cover must have a 2-in.-deep lip or flange all around for stiffening (Fig. 6.5). The cover must also be stiff enough, or reinforced, so that it will not "oil can" under pressure variations to which it may be subjected. The cover and the cover-clamping mechanism must be capable of sealing the cover opening whether or not a bag is in place.

6.2.3 Bagging

Most commercially manufactured and some one-of-a-kind shop-built housings are designed for bag in, bag out filter replacement. Figure 6.8 illustrates a step-by-step description of this procedure. As noted in the drawings, shutoff dampers are needed upstream and downstream of the filter (or other component being replaced) to permit isolation of the housing during the change, and to prevent ballooning or sucking in of the bag, when the cover is opened, due to a pressure differential between the inside and outside of the bag. A small, valved, breather vent is required on the clean side of the filter to control pressure in the housing; a slight negative pressure ($\frac{1}{4}$ to $\frac{1}{2}$ in.wg) helps ensure inward leakage should the housing become pressurized due to pumping of the bag. When heat-sealing plastic bags, two seals about 1 to 2 in. apart are usually made so that when the bag is cut between them both the housing opening and the plastic-enclosed filter are sealed from the room environment. One operator makes three heat seals and cuts the bag on the middle one, which makes for a better seal and gives added protection in the event one of the outer seals is defective. Heat sealers capable of spanning at least a third of the bag width are available commercially.

Bags must be of clear plastic to permit the worker to see what he is doing (in the Vokes and Flanders housing designs, for example, the worker must manipulate the filter clamping mechanism through the bag.) Bagging materials are polyethylene or polyvinyl chloride, 0.006 to 0.008 in. thick. Because the bags tear and abrade easily, particularly when used with metal-cased filters or adsorbers, the thicker material is preferable, and care must be taken when carrying out the procedure with larger (24 × 24 × 11$\frac{1}{2}$-in.) items. Although bag-out housing manufacturers often advertise that a major advantage of their design is that housings can be installed inside the laboratory with no additional protection, the fact that bags tear readily makes this a dubious statement. Housings should be installed in a room that can be isolated as a contamination or radiation zone in the event of a bag tear and resultant spill. The excess bag material that remains after a new filter is placed into the housing is folded carefully against the side of the filter element, as shown in Step 8 (Fig. 6.8), to prevent any portion of it from getting into the airstream or being pinched between the housing cover and bagging ring. The bag, after it is folded within the filter housing, must be isolated from system airflow on the clean side of the filter, because the plastic can be damaged from continued exposure to the airstream. Covers of bag-out housings must be capable of sealing the housing with and without the bag installed and must be kept closed when the system is in operation to protect the bag that remains in the housing. Bagging should not be considered an automatic solution to the contamination hazard, and the user is cautioned to take proper precautions during filter changes. Figure 6.9 shows the proper dress for personnel engaged in a bag-out filter change when there is the possibility of high contamination levels. Note the full body cover and gas mask.

6.2.4 Housing Installation

For multifilter installations (Sect. 4.4.1), horizontal airflow, with filter faces vertical, is recommended for large (24- by 24-in. face dimensions) HEPA filters. This recommendation is not so important for smaller filters that have sufficient media support inherent in their design to resist gravitational pull on filter core and collected dust. When vertical airflow (face of filter horizontal) is unavoidable, upflow is recommended for all sizes for the reasons given in Sect. 4.4.2. Unlike multifilter installations, installation of the filter on the clean side (i.e., downstream) of the mounting frame is always recommended for single-filter installations. Except for the common practice of installing furnace filters directly to or adjacent to the HEPA filter, back-to-back installation of prefilters or adsorbers to HEPA filters should be avoided. Because of test and fire safety considerations, a distance of 4 to 5 ft between the HEPA filter and a prefilter or adsorber cell is recommended. If a flame arrester is provided in the system, it must be far enough upstream (usually 1 to 2 ft) of the prefilter or HEPA filter to diffuse any flame that penetrates the arrester.

For multistage installation, components may be installed in a single housing, as Fig. 6.4 shows, or in

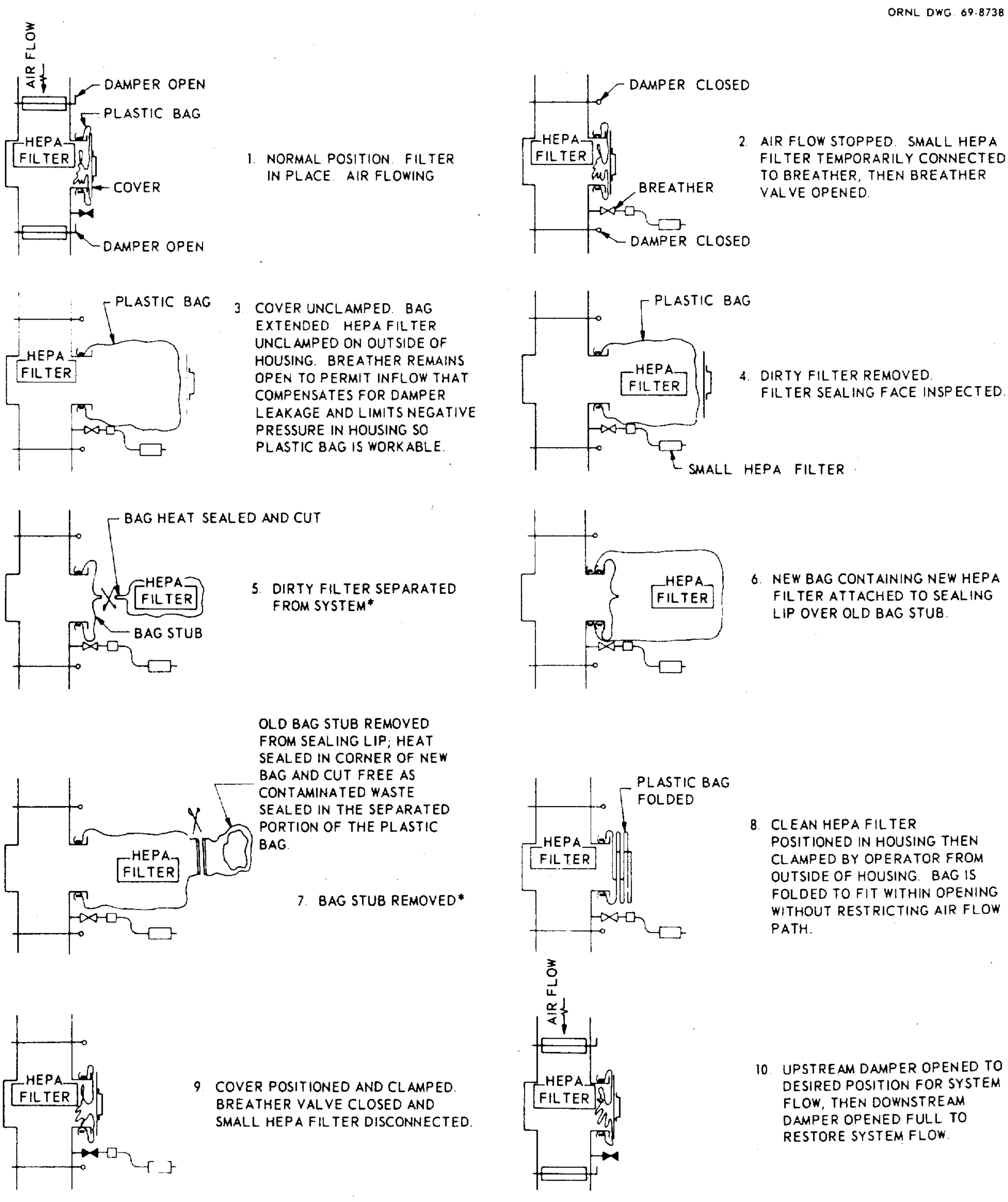


Fig. 6.8. Procedure for bag in, bag out filter (adsorber cell) change. *One operator makes three heat seals and cuts the bag on the middle one; if carefully done, this procedure leaves no contaminated surface.

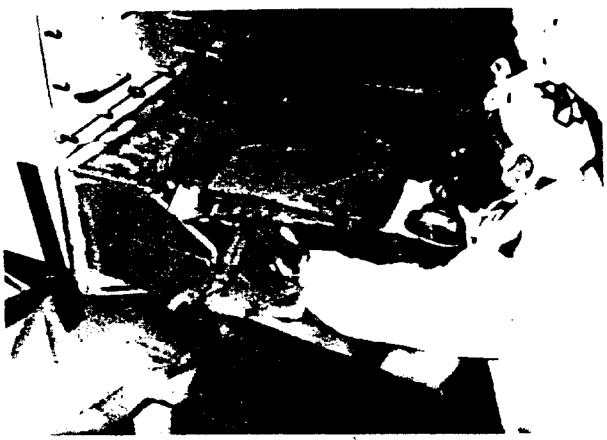


Fig. 6.9. Recommended attire for personnel engaged in contaminated filter handling, including bag-out filter change. Note full body covering and respiratory protection. Courtesy Director, Atomic Weapons Research Establishment, Aldermaston, United Kingdom.

interconnected individual housings as Fig. 6.10 shows. Although bolted, gasketed joints (Fig. 6.11) are recommended, flexible connections (Fig. 5.14) are suitable for housings connected directly to a fan. Duct-tape seals between housings and ductwork are unacceptable. Multistage installations create problems from the standpoint of periodic surveillance testing of HEPA filters and adsorber cells (Chap. 8). As Fig. 6.11 shows, even though a flange-to-flange installation is undoubtedly the least expensive from the standpoint of materials and space occupancy, there may be insufficient room between components to introduce a well-mixed test agent, to obtain a satisfactory upstream sample, or to probe for leaks on the downstream faces of the components. Careful planning of filter and adsorber test procedures, before design of the installation is completed, is essential, particularly for multistage installations. Although some housing specifications require, and some vendors routinely furnish, sample ports in the housing itself, such ports should not be automatically considered as meeting the requirement for preplanned and preinstalled test ports. As noted in Chap. 8, the test agent injection port must be located well upstream of the filter or adsorber to achieve good mixing of air and agent. Upstream samples must be taken from a point in the duct that is immediately upstream of the filter or adsorber. Downstream samples must be taken at a point far enough downstream to obtain good mixing of the air and test agent that penetrates the filter or adsorber. This point is at least 10 duct diameters downstream, or preferably downstream of the fan. Figure 6.12 shows features that should be considered in the design of a single-filter installation. Fire protection is discussed in Sects. 2.5.2 and 9.5.

6.3 ENCLOSED FILTER INSTALLATION

Enclosed HEPA filters often appear to offer an ideal solution to some in-duct requirements. They are, by design, unitary; they do not require enclosures; and, after removal from the duct, they can be sealed and handled without personnel coming in contact with the contaminated filter core. However, they must be used with caution. First, the wood-cased type, because the case is part of the system pressure boundary, does not meet the requirements of the National Fire Codes (specifically NFPA 90A)[2] and should not be used in any application where the potential of a filter fire exists. Second, steel-cased enclosed filters are notorious for leaky cases and

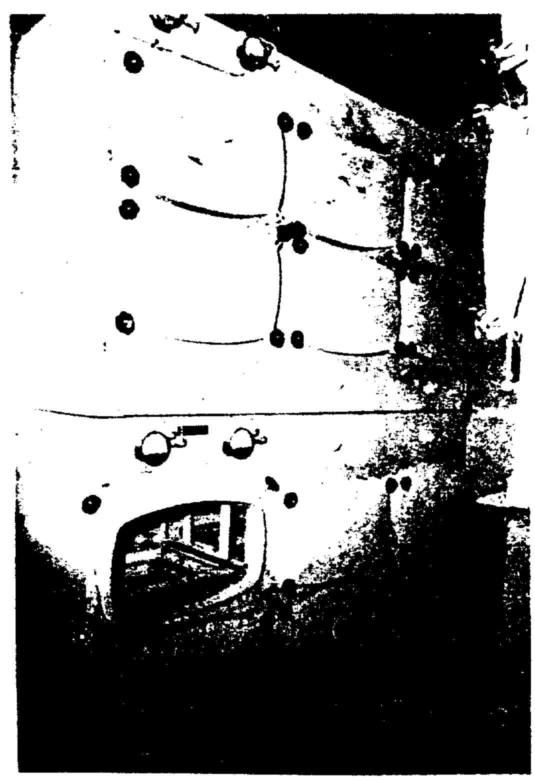


Fig. 6.10. Large capacity air cleaning system employing bag in, bag out multifilter caissons. Courtesy Allied Chemical Co., Idaho Falls, Idaho.

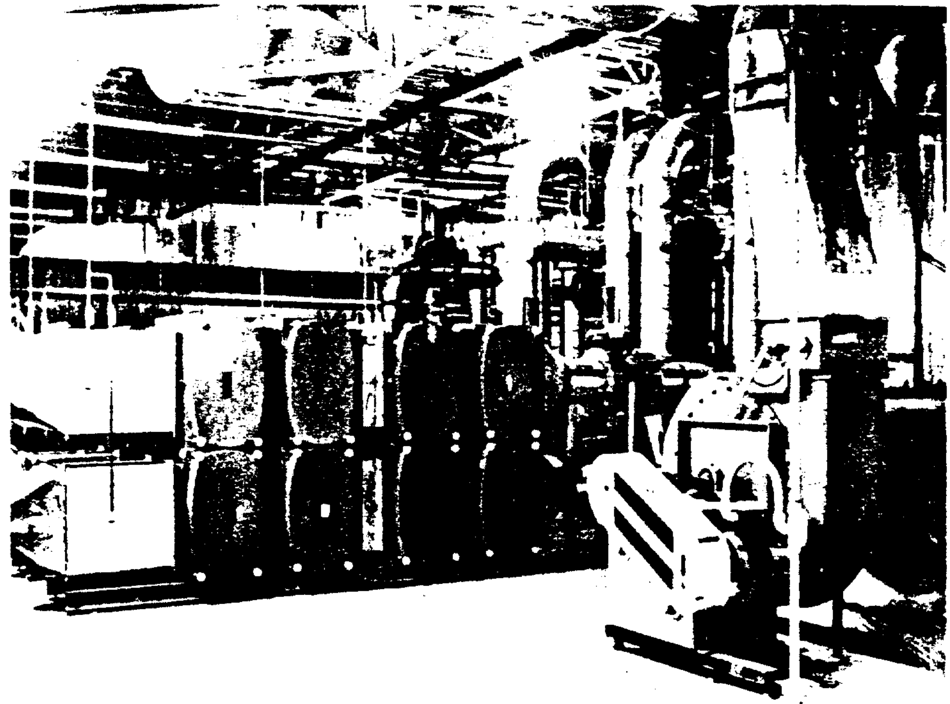


Fig. 6.11. Two-branched multistage air cleaning system employing individual single-filter caissons. Courtesy MSA Co.

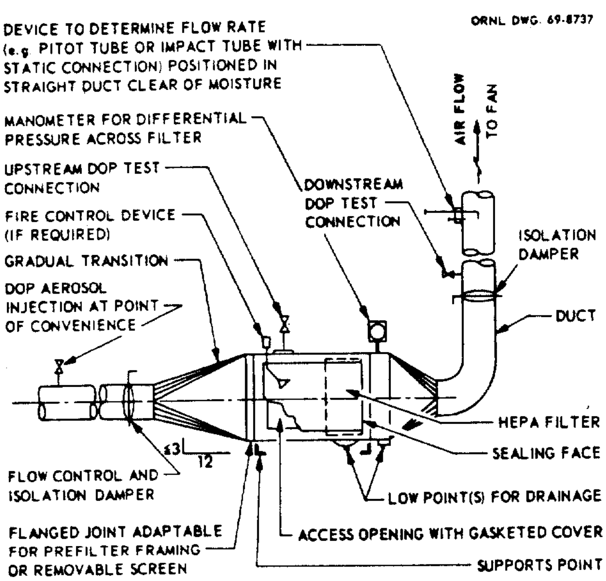


Fig. 6.12. Features of single-filter housing installation.

should not be used in positive-pressure applications or where the filter case could be pressurized under system-upset conditions. The case is part of the system pressure boundary. Although the filter core is adequately sealed into the case to prevent leakage between case and core under normal airflow, air can leak through the joints of the case, which are simply riveted through a layer of compressed glass-fiber matting. This seal is not airtight and, under positive pressure, is not an effective particle filter. For this reason, it is recommended that when steel-cased enclosed filters are to be used in systems in which there are, or could be, significant levels of contamination, the filters be bagged at all times, as shown in Fig. 6.13.

Enclosed filters are most commonly furnished with plain nipple ends, as Fig. 3.3 shows, and are generally sealed into the duct by means of (1) flexible tubing and clamp rings (Fig. 6.14); (2) specially designed elastomer sealing glands or cuffs (Fig. 6.15); or (3) a

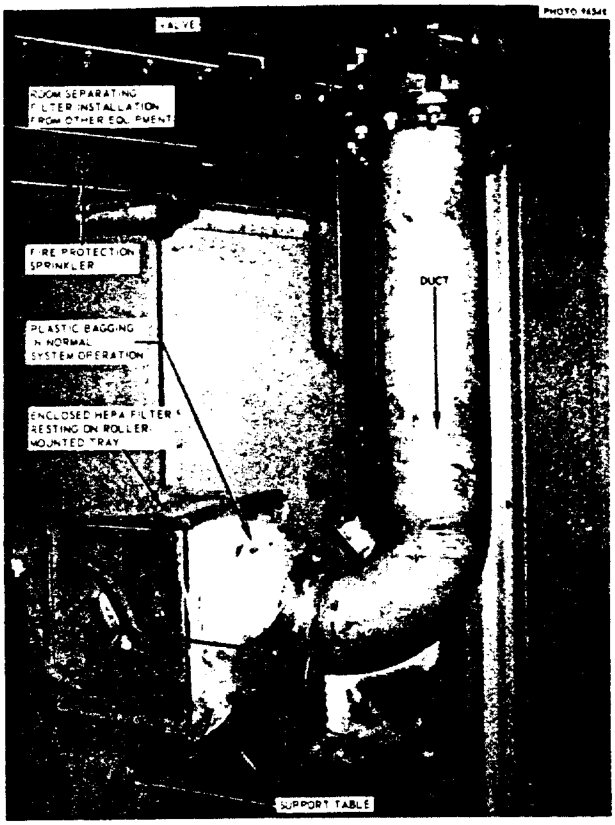


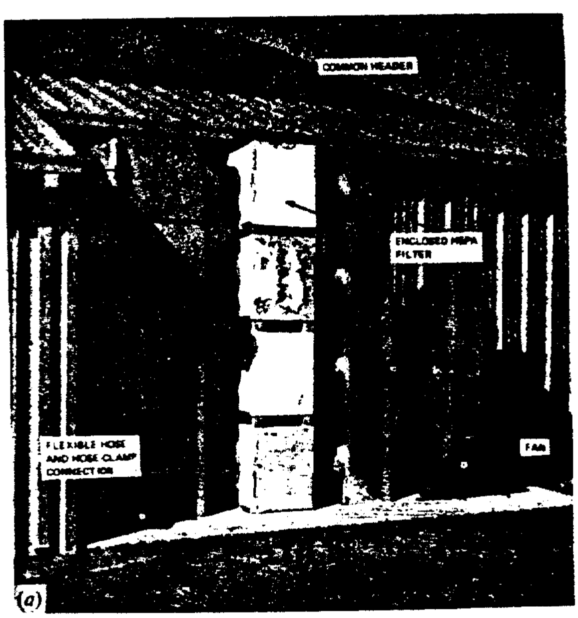
Fig. 6.13. Steel-cased enclosed-filter installation showing plastic bagging to prevent outleakage of particulates and inleakage of air.

wrap of duct tape. The third method is not reliable and, if used, the tape should be protected with a metal collar as Fig. 6.16 shows. All of these seals are subject to failure when exposed to fire or hot air and cannot be recommended for applications where high levels of radioactivity may be present. Flanged joints are the only type that can withstand extended exposure (more than 10 min) to high temperature air or to fire imposed from either inside or outside the duct.

Individual filter supports, such as those in Fig. 4.2, are recommended. In the installation shown in Fig. 6.14*a*, temporary supports for the upper units would have to be built to permit replacement of one of the lower filters. As with open-face filters, horizontal airflow through enclosed filters is recommended.

6.4 CYLINDRICAL FILTER ELEMENTS

The cylindrical HEPA filter is another configuration that often appears to offer ideal solutions to certain installation requirements. However, this type of filter must be used with caution because of



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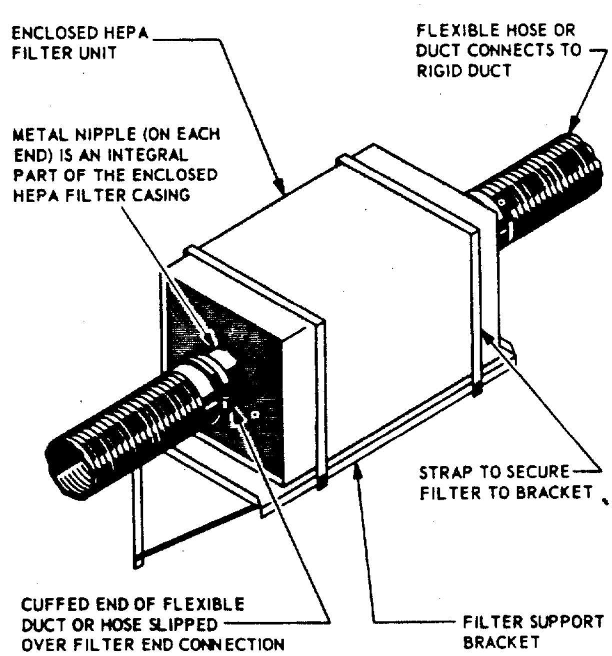


(*b*)

Fig. 6.14. Typical flexible-tubing and clamping-ring installation of enclosed HEPA filters. (*a*) Multiple installation of wood-cased enclosed filters between common supply and exhaust plenums. Note lack of individual filter supports. (*b*) Typical installation of steel-cased enclosed filter in glove box application. Note support bracket and straps to secure filter element.

shortcomings in its construction. One manufacturer makes a spiral of the filter material and a separator; the others make a conventional pleated-medium-and-separator core that is trimmed to cylindrical shape. In both designs, the core is slipped into a molded or welded-seam cylinder and sealed by catalyst-activated plastic foam or an adhesive. There is no interference or pressure fit between core and

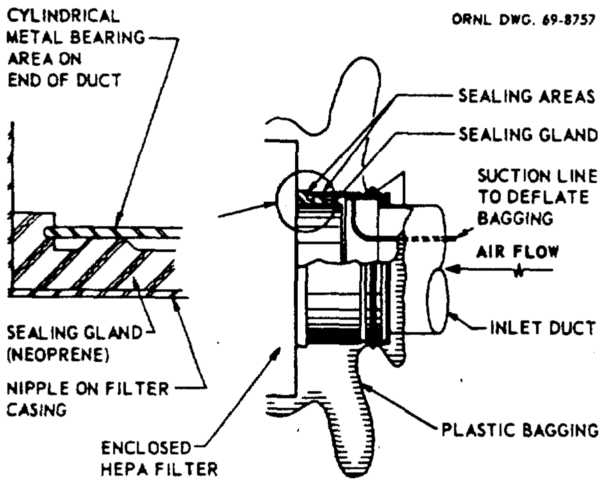


Fig. 6.15. Specially designed elastomeric gland for sealing enclosed filter into duct.

casing, as in the open-face and enclosed rectangular configurations, because the core would be damaged when fitted into the case. In addition, because the cases are often made from light gage, easily deformed sheet metal, they are often considerably out-of-round. The result is often a filter element that leaves much to be desired from the standpoints of leak integrity after a period of service and resistance to the exigencies of air cleaning system service.

Cylindrical HEPA filters can be obtained with or without flanges on one or both ends. The filters without flanges are used in push-through (so-called incessant) installations; the filters are sealed into a cylindrical opening with one or more half-round circumferential gaskets (fixed to the filter) which make a slight interference fit with the receiver. Inasmuch as the filters are often out-of-round and a reliable interference fit between filter and receiver is impracticable, push-through installations are often unreliable under system-upset conditions. Push-through filters are subject to being blown out of the receiver if pressure differentials become high. Flanged cylindrical HEPA filters can be installed in openings of pipes by bolting them to a flange on the pipe or by clamping the filter flange between mating pipe flanges. Conventional neoprene sponge gaskets

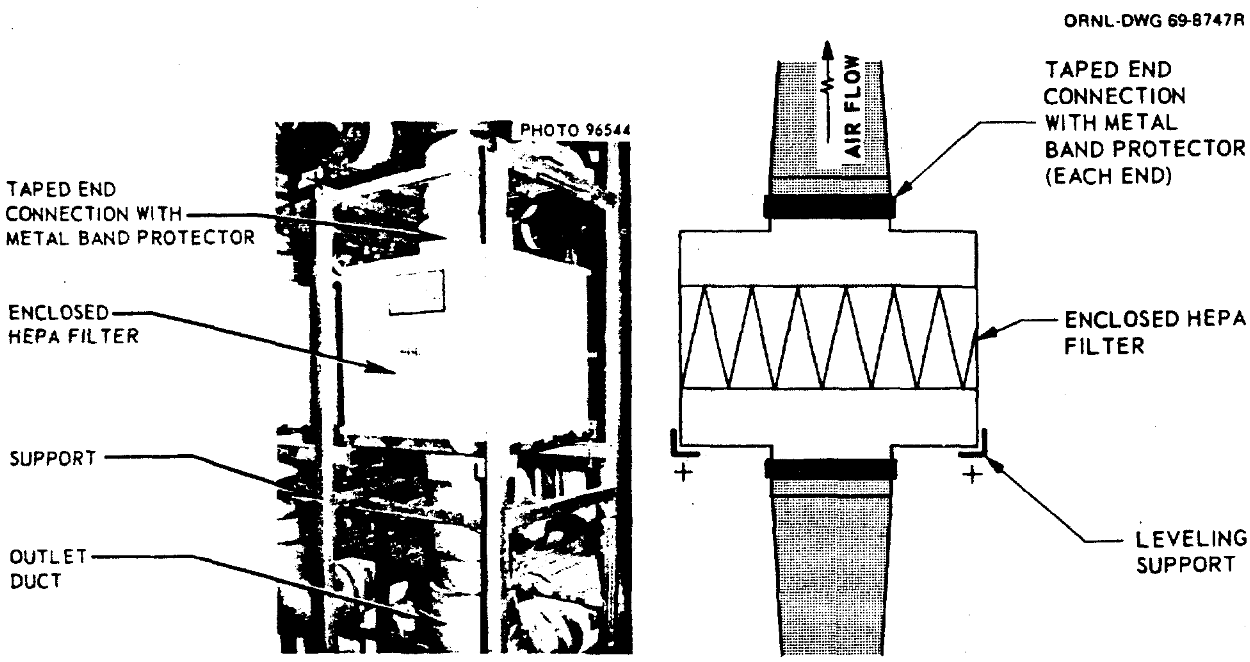


Fig. 6.16. Enclosed filter installation. Note taped connections with metal-band protectors, support for filter. Downward airflow is poor, because (1) airflow and gravity combine to impose an unnecessary pressure condition on the filter core, and (2) if condensation occurs in the pleats of the filter, contamination can seep through with the condensed liquid and contaminate the clean side of the system.

are used for sealing (Sect. 4.3.4). Because filter flanges and cases are characteristically made from light-gage sheet metal with the flange seal-welded to the cylinder, these filters often leak at the flange-to-case weld. The flange often becomes deformed. Either condition results in an installation that is difficult to seal.

Cylindrical HEPA filters cost substantially more than rectangular HEPA filters of equivalent airflow capacity. In most cases they should be considered as "specials," because manufacturers generally do not stock them. There are no standard dimensions or airflow capacities, and those listed in the manufacturer's catalogs are generally simply those that have been special-ordered by another purchaser at an earlier date. No cylindrical filters are rated under UL-586[4] or listed in any of the standard specifications for HEPA filters (e.g., MIL-F-51068, IES CS-1). Cylindrical HEPA filters are characteristically of relatively small diameter (less than 12 in.) and airflow capacity. The authors know of only one 1000-cfm cylindrical HEPA filter installation. In this case the filter was installed horizontally with downward airflow; it had to be replaced frequently because of mechanical damage resulting from high moisture loadings, the unfavorable filter configuration, and unfavorable installation practices. The operator eventually replaced the cylindrical filter with open-face rectangular units which could be bought from stock at a fraction of the price of the special cylindrical elements.

Figure 6.17 shows two methods of installing cylindrical filters, one a duct-entrance design and the other a hot-cell exhaust design. In the hot-cell exhaust design, the mounting is sloped to permit runoff of any liquid accidentally spilled on the shield that protects the filter, and to facilitate handling by the cell electromechanical manipulators. Where cylindrical HEPA filters are used, liberal clearance (at least $^1/_8$ in. all around) between the case and receiver is necessary to accommodate the characteristic out-of-roundness. The advantage of cylindrical filters is close conformance to round ducts and pipes, which can permit the use of smaller and cheaper duct transitions and less space requirement. For in-line installations, however, except where the filter has flanges on both faces and is installed as a spool piece, provision must be made to extract the filter from the duct or pipe after the connection is broken, with the result that the space advantage over an equivalent open-face rectangular filter may be lost. Spool-piece filters must have flanges that can withstand the forces imposed by the duct or piping system, and the flange bolting.

Cylindrical filters are often used in radioactive vacuum cleaners and portable air purifiers (Fig. 6.18). The air purifier shown is a single-use device that is discarded when the contamination level or pressure drop of the collectors becomes greater than some preestablished design level, or the arresting efficiency of the collectors drops below a preestablished design level (usually 99.97% for the

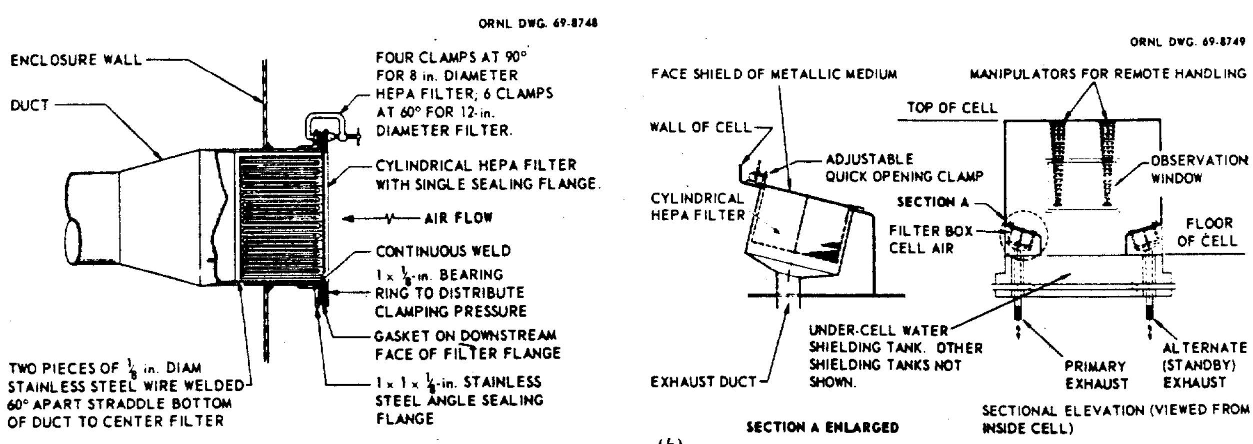


Fig. 6.17. Typical cylindrical HEPA filter installation. (*a*) Installation designed for contact maintenance. (*b*) Installation designed for remote maintenance.

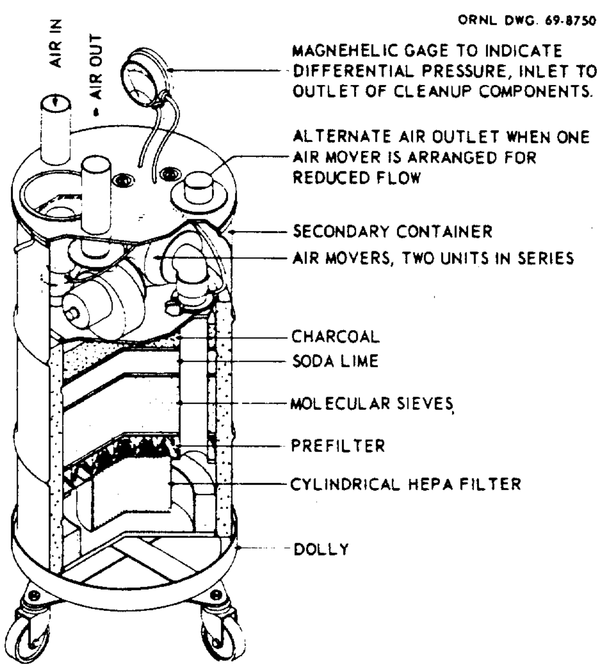


Fig. 6.18. Dry air purifier employing cylindrical HEPA filter.

filter). The air purifier was provided to clean a low-volume flow of off-gas evolved during the processing of high-level transcurium elements.[7] Although an open-face rectangular filter element could have been used in a somewhat different arrangement, the use of the cylindrical element was a designer's option, not a requirement of the application. As a general rule, the use of the rectangular filter is recommended wherever practicable.

6.5 INSTALLATION

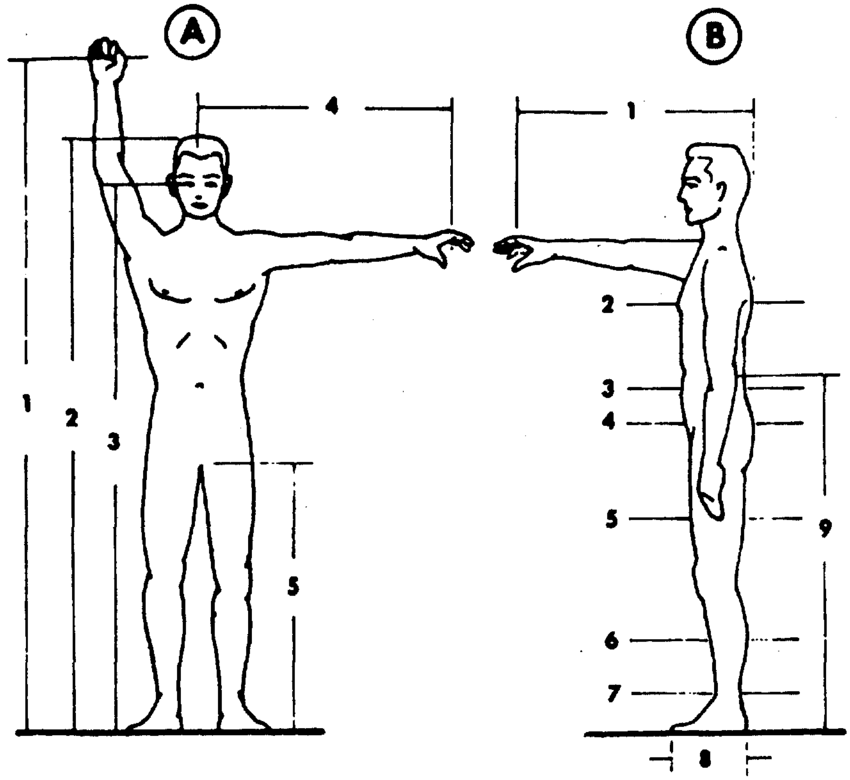
6.5.1 Human Factors

The recommendation to install filters vertically, with horizontal airflow, is discussed in Chap. 4. When practicable, single-filter installations should be located where they can be reached for service and testing without requiring workers to climb ladders or scaffolding. This requires a consideration of human engineering factors, that is, the reaching and lifting capability of the average man. Figure 6.19 shows dimensions for the 5th and 95th percentile man. Dimensions of female workers are substantially smaller.[8] Extrapolation of the recommended weight limits given in Fig. 6.20 indicates that handling a 1000-cfm HEPA filter, in the body positions often encountered in filter-change operations, is at the upper range of personnel capability (higher loadings result in lower man-efficiency) and that handling of adsorber cells is well beyond the limits for one person. Consideration must be given to the positions that a worker must assume to perform the required task. If he must hold his hands overhead for any length of time, he becomes fatigued. If he has to crouch, bend, or squat, he will soon become stiff, which will contribute to his loss of efficiency. If a worker has to hold a heavy weight while performing a precision operation (e.g., supporting the weight of a filter or adsorber cell while trying to fit it between duct transitions or into a restricted opening), the stress of the combined task becomes fatiguing and he is apt to make a mistake.[8] All of these factors are compounded when the worker must wear protective clothing and respiratory protection. In addition, protective clothing adds to his spatial requirements and limits his mobility. For HEPA filter and adsorber cell installations, location of the filter or housing at an elevation between knee and shoulder height (Fig. 6.19) is recommended.

6.5.2 Fume Hood Filter Installations

The wide and often unpredictable variety of chemical operations conducted in laboratory fume hoods makes the selection and installation of HEPA filters difficult and uncertain. Corrosive fumes may damage the filter and its mounting, and moisture and heat from hood operations may accelerate the damage. Operations that produce steam or moisture should be restricted to minimize condensation in, or the carry-over of water and/or chemical droplets to, the filter core.

Figure 6.21 shows a wood-cased enclosed HEPA filter installed immediately downstream of a fume hood and within the laboratory. This installation presents a threat to the laboratory in the event of a spill during a filter change and necessitates interruption of laboratory operations when the filter is changed or tested. Some facilities install the fume hood filters in the attic, usually directly above the hood served, as shown in Fig. 4.1. Where such design is employed, the attic space should be designed as a contamination zone, providing for ease of cleanup in the event of a spill, and should not be used for extraneous purposes such as storage and experimental work when radioactive materials are handled in the hood.



MALE HUMAN BODY DIMENSIONS

Selected dimensions of the human body (ages 18 to 45) suitable for initial design of crew space and equipment. Locations of dimensions correspond to illustrations on the page at the left.

	DIMENSIONAL ELEMENT	DIMENSION (in inches except where noted)	
		5th PERCENTILE	95th PERCENTILE
	Weight	132 LB	201 LB
A	1 Vertical reach	77.0	89.0
	2 Stature	65.0	73.0
	3 Eye to floor	61.0	69.0
	4 Side arm reach from CL of body	29.0	34.0
	5 Crotch to floor	30.0	36.0
B	1 Forward arm reach	28.0	33.0
	2 Chest circumference	35.0	43.0
	3 Waist circumference	28.0	38.0
	4 Hip circumference	34.0	42.0
	5 Thigh circumference	20.0	25.0
	6 Calf circumference	13.0	16.0
	7 Ankle circumference	8.0	10.0
	8 Foot length	9.8	11.3
	9 Elbow to floor	41.0	46.0

Fig. 6.19. Male human body dimensions. From W. E. Woodson, *Human Engineering Guide for Equipment Designers*, University of California Press, 1966.

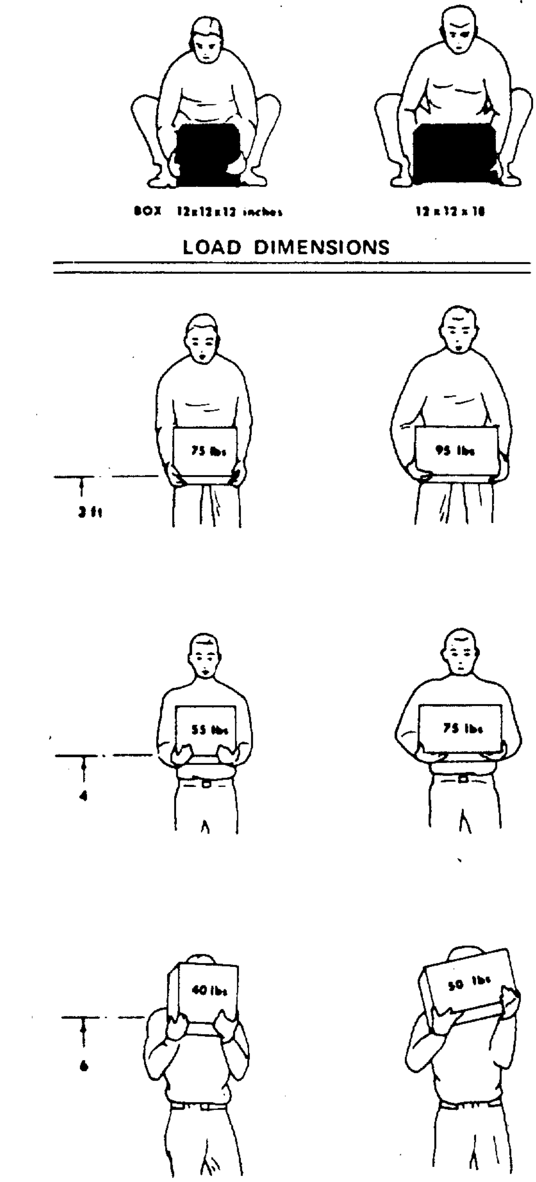


Fig. 6.20. Recommended weight limits for 95th percentile male and maximum loads that should be handled in various body-load orientations and load-heights. From W. E. Woodson, *Human Engineering Guide for Equipment Designers*, University of California Press, 1966.

Hoods in which perchloric acid and certain other chemicals are handled should be provided with washdown facilities to permit periodic decontamination of the hood and ductwork (perchloric acid hoods should not be used for handling other materials because of the explosion hazard). Off-gas scrubbers are often provided in hoods. Both washdown facilities and scrubbers generate substantial quantities of sensible water droplets. Provision of demisters that meet the requirements given in Sect. 3.5 should be considered for protection of the filters and their mountings. Moisture collected in the demister should be conducted to a hood drain rather than permitted to fall back into the work space of the hood. Demisters should have adequate handling space and be easily accessible for cleaning, inspection, and replacement. Where incandescent particles or flaming trash can be released to the hood exhaust stream, a spark arrestor may be needed to protect the HEPA filter. This arrestor can be either a commercial flame arrestor, a metal-mesh graded-density demister, or as a minimum, a piece of 40-mesh metal cloth. In any event, the arrestor must be located at least 1 to 2 ft ahead of the HEPA filter and must have easy access for cleaning, inspection, and replacement.

Heat sources such as heating mantles, furnaces, and Bunsen burners are common equipment in laboratory fume hoods and should be planned for in the initial hood and exhaust system design. Extended lengths of duct between the hood and filter can

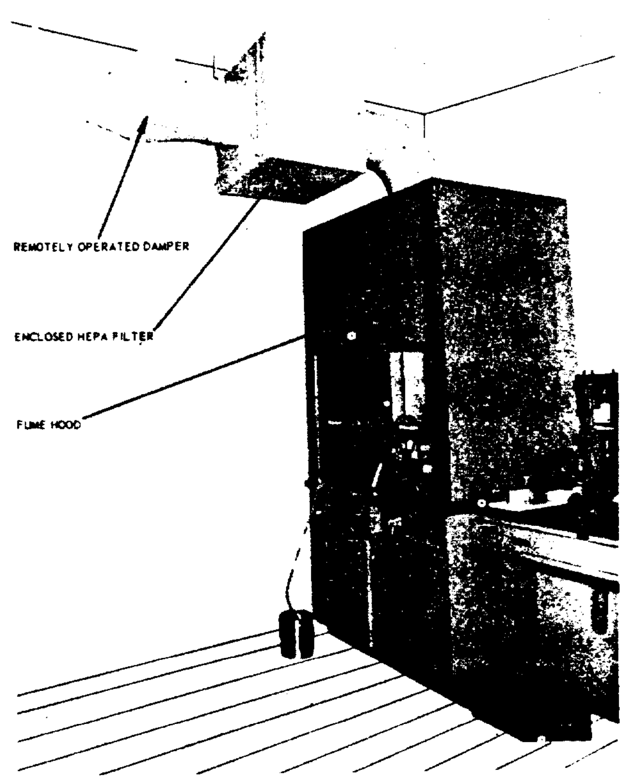


Fig. 6.21. Wood-cased enclosed HEPA filter installation for laboratory fume hood.

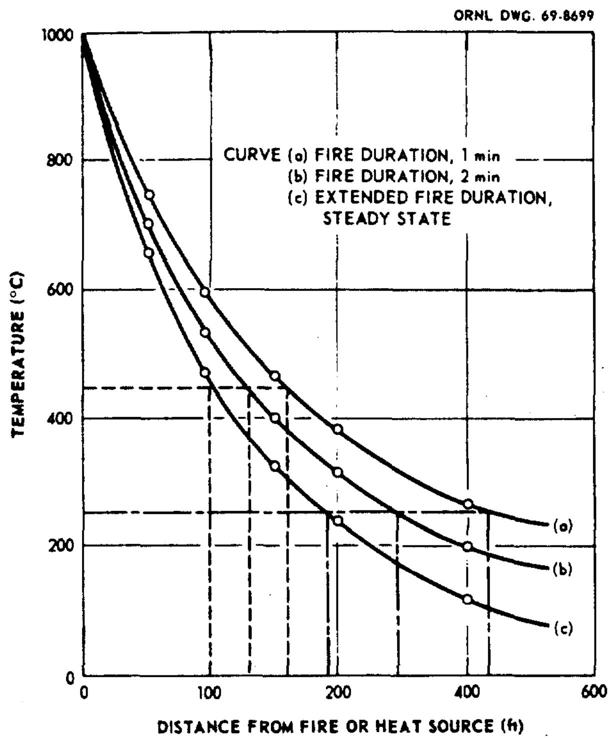


Fig. 6.22. Cooling rate of air in a 12-in.-diam duct carrying 1000 cfm of air. Dashed lines show the length required to cool the air from an initial temperature of 1000°C (1832°F) to 450°C (842°F) and 250°C (482°F) for various fire conditions. From S. E. Smith et al., *Protection Against Fire Hazards in the Design of Filtered Ventilation Systems of Radioactive and Toxic Gas Process Buildings*, UKAEA Report AWRE O-24/65, Atomic Weapons Research Establishment, United Kingdom, July 1965.

provide substantial cooling, but to be really effective, a length of at least 100 ft is needed (Fig. 6.22). Such a length is often impractical, and control of heat-producing operations by limiting the size of heat sources, insulation of furnaces, etc., or use of air cooling methods such as sprays, must be relied upon. Chapter 9 discusses operational control for fire prevention and heat control in HEPA filter systems.

6.5.3 Emergency and Portable Air Cleaning Units

Figures 6.23 and 6.24 show portable air cleaning units used for emergency and temporary air cleanup applications. The emergency system in Fig. 6.23 is an army CBR unit and fan installed on a common skid that can be transported by truck or airplane. The CBR unit, which contains a HEPA filter (1000 cfm) and a multitray adsorption unit, was designed for attachment to a small reactor containment structure in the event of an accident. The portable unit in Fig. 6.24 is conceptually the same but employs a HEPA filter and either a prefilter or pleated-bed (type I) adsorber cell installed in individual commercially built caissons. The selection and installation of enclosures (caissons) and components in units such as these should adhere to the same principles discussed earlier. Because the unit in Fig. 6.24 can accommodate only a 1-in. pleated-bed adsorber cell, it is not satisfactory for service in which high arresting efficiency for radioactive organic iodine compounds is required. Figure 6.25 shows a superior design,

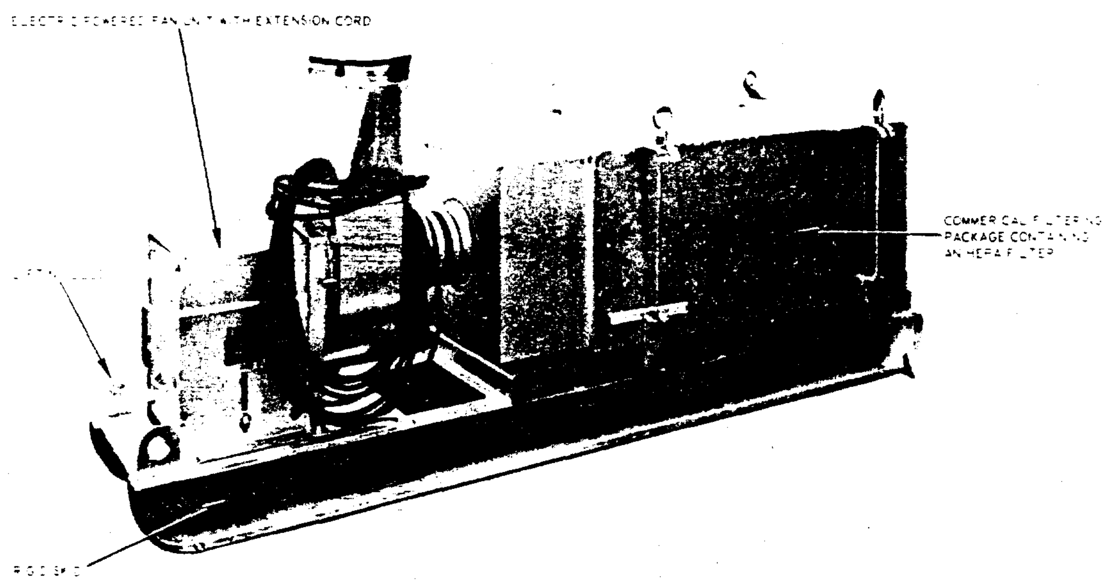


Fig. 6.23. Emergency air cleaning unit consisting of a CBR unit and fan mounted on a common skid, transportable by truck or plane. Courtesy Lawrence Livermore Laboratory.

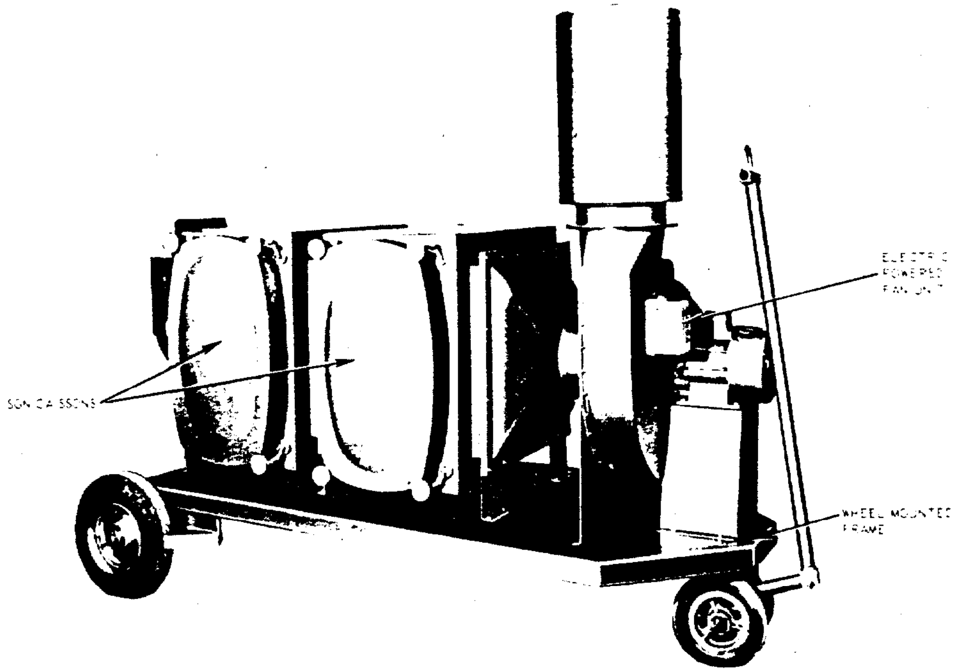


Fig. 6.24. Portable air cleaning unit consisting of two 1000-cfm caissons and fan mounted on a cart. Courtesy Sainte Gobain Nucléaire.

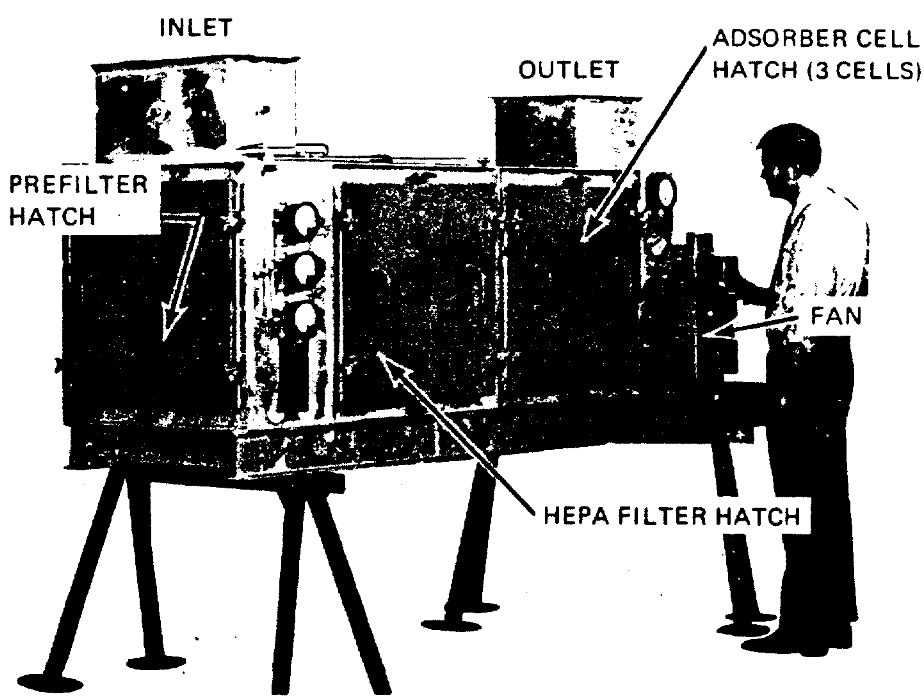


Fig. 6.25. Transportable air cleaning unit consisting of a heavy-duty enclosure containing prefilter, HEPA filter, three type II adsorber cells, and fan mounted on a common skid. Transportable by truck or plane. Courtesy CTI-Nuclear, Inc.

employing a prefilter, 1000-cfm HEPA filter, and three 2-in.-bed tray-type (CS-8 type II) adsorber cells.

Emergency and portable air cleaning units require the same periodic inspection and in-place leak testing as permanently installed systems. The rough handling and shock they can be expected to experience during transport makes careful inspections and functional tests desirable prior to each use. The skid and framing assembly must be rigid and capable of absorbing the shocks that can be expected from the transport environment and handling.

Figure 6.26 shows a portable HEPA filter installation that can be used for temporary exhaust service. Portable hoods and enclosures are often used in nuclear plants for spot protection of temporary operations or inadvertently contaminated areas. These situations do not warrant the expense of a complete air cleaning unit and the need can often be met by a simple arrangement such as the one shown in Fig. 6.26. This device can be connected to any duct of a central exhaust system by a flexible hose and used to ventilate contained spaces such as a manhole, tank, vault, hood, or enclosure. For such temporary installations, sealing the filter into its housing using a wrap of duct tape is satisfactory. If the portable installation becomes contaminated, the whole assembly can be discarded as a throwaway item and replaced at moderate cost.

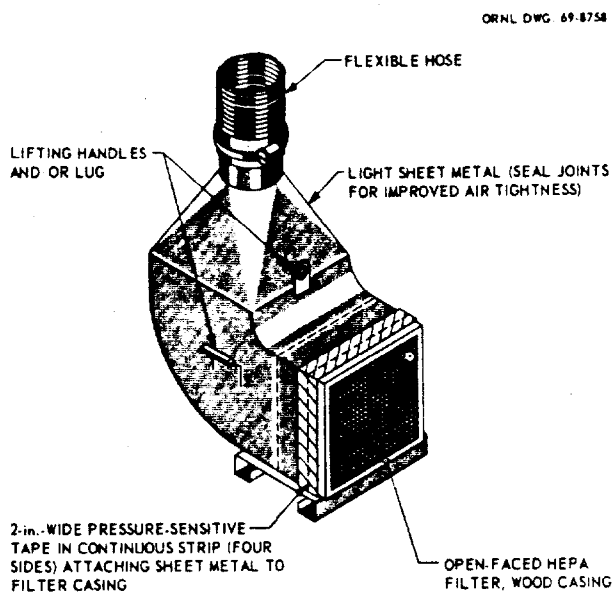


Fig. 6.26. Low-cost filter enclosure for temporary service.

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